3.2 Hydroelectric Power Generation

3.2.1 Summary

This section of the report concerns hydropower's contribution to the least-cost plan. To meet the analysis objectives, an assessment was made of the existing and planned hydropower projects that are considered to be suitable for inclusion in such a plan. As specified in the terms of reference, the studies were based, for the most part, on existing information.

For the existing projects, information was collected from available reports and supplemented with information collected during investigations. For the planned sites, studies ranging from conceptual to detailed feasibility studies were utilized.

3.2.2 Condition Assessments of Existing Projects

The process involved in developing the required information for the least-cost development plan was to perform an initial screening to identify a reasonable number of real opportunities for development, the analysis of the information collected for these projects, and the development of cost and other information for inclusion in the least-cost model.

The contents of the various sources of data are varied. Much of the information gathered from the data sources is conflicting, even with respect to the nameplate capacities of the units. It was assumed that any feature described as needing repair still needs repair unless a later assessment specifically indicated that the feature was repaired. Therefore, the estimates represent an accumulation of all of the items identified. In the text of this Report, not all items are mentioned, as this information is readily available from each of the sources, but a general condition assessment is presented as well as the specific identification of the major items needing repair, rehabilitation, or refurbishment.

The total installed hydroelectric capacity in Armenia is reported to be 1,023 MW distributed among 13 major hydropower plants. As a result of the initial screening, 11 projects were identified (excluding small hydro projects) for which a thorough data-gathering program was initiated. Characteristics of the 13 existing projects are presented in Table 1.

Table 1 Existing Hydro Projects - Key Data

	Installed	Generation, GWh/yr.		Total Cost (2000 $)	
Project	**Capacity, MW**	**Existing**	**Rehab/ New[1]**	**Million $**	**$/kW**
Sevan-Hrazdan HPP Cascade[2]					
Sevan	34.2	29.7	29.7	3.43	100.29
Hrazdan	81.6	89.1	89.1	2.55	31.25
Gumush	224	219.8	219.8	10.49	46.8
Arzni	70.6	75.1	75.1		
Kanaker	102	85.9	85.9	21.93	215.00
Yerevan-1	44	40.5	40.5	1.49	33.86
Yerevan-3	5	0	0		
Cascade Total	*561.8*	*540.0*	*540.0*		
Vorotan HPP Cascade[3]					
Tatev HPP	157.2	573.4	427.0	8.26	52.54
Shamb HPP	171	216.2	161.0	16.80	98.26
Spandaryan HPP	76	131.6	98.0	6.82	89.74
Her-Her HPP	1.26	18.8	14.0		
Cascade Total	*405.5*	*940.0*	*700.0*		
Other and Small					
Dzorages[4]	25	50.6		Private Rehab.	
Small	31	70.4			

Cost Estimating

More than one-half of the hydro plants under consideration are more than 40 years old, and many of the remainder are more than 20 years old. The age by number of plants and capacity (excluding small hydro plants) is:

Plant Age	No. of Plants	Installed Capacity, MW
0-20 years	2	77.3
21-30 years	2	328.2
>40 years	8	586.8

In addition to deterioration because of age, all of the plants have been subjected to severe operating conditions due to a lack of funds for maintenance over the last 10 years. Even the younger stations

[1] Water tunnel Vorotan-Arpa is completed. Water is diverted from Vorotan Cascade to Lake Sevan. Energy production decrease at Vorotan Cascade is 240-260 GWh/year.
[2] Sevan Hrazdan investment data taken from Assessment Report on Rehabilitation of Vorotan and Sevan- Hrazdan Cascades, Including Dzora HPP, Hagler Bailly, April 1999 and escalated at 3.5%/yr.
[3] Investment data taken from Vorotan Hydropower Cascade Rehabilitation Project Planning and Technical/Financial Analysis Report, Hagler Bailly, November 1999.
[4] Taken from 1996 Update Least Cost Power Investment Program for Armenia, Lahmeyer International, November 1996, and escalated at 3.5%/yr.

are in very poor condition. Spending substantial funds to repair known problems may not be an appropriate solution because essentially all of the equipment is at or is rapidly approaching incipient failure. For optimal operation the solution is probably to replace most of the equipment. However, since there remains considerably more capacity than peak load in Armenia and most of the hydroelectric projects are water-constrained, the best approach might be to repair only what is necessary to keep the plants running, and to replace equipment only when it fails. As long as funds are available to repair or replace equipment on an as-needed basis, this approach could be acceptable. This may be particularly true for the Sevan-Hrazdan Cascade projects, as water for irrigation is the primary source of water. Some of the plants are also oversized in terms of the ratios of their rated capacities to available energy. At the time of their design, high levels of generating capacity were built to provide peaking power operations to serve the lower part of the USSR.

For the least-cost planning study, the estimates reflect an early expenditure of funds to replace equipment rather than trying to repair what has been identified as needing repair at this time. As such, the estimates are higher than previous estimates. Although the concept slightly penalizes the projects by not phasing in costs to the best extent possible, it is expected that the funds identified in this estimate will be needed in the near-term. In addition, many items that are normally handled under operation and maintenance programs are not included in the capital estimates. In most cases these items are inexpensive and not critical.

In a prior study, to prioritize the expenditures for hydroelectric rehabilitation, the Kanaker project on the Sevan-Hrazdan cascade and the entire Vorotan Cascade were identified as the highest priority items. After these projects, some rehabilitation needs remain on the Sevan-Hrazdan Cascade and also at the Dzorages station. Maintenance of these two projects in an operative condition is necessary to gain generation from natural and irrigation flows; however, to the extent that the level of capacity provided by Vorotan and other resources is high, the need for dependable capacity from these projects diminishes.

Operating Costs

Operating and maintenance (O&M) costs include operation, maintenance, and replacement. They are defined as the average annual expenditures of labor and materials necessary to keep a project operating at near optimum efficiency throughout its useful life. O&M costs include salaries of the operating personnel, the cost of labor, plant, supplies for ordinary maintenance, and the cost of spare parts. Replacement costs include components that require replacement prior to the end of the project life, such as stator windings, turbine runners, thrust bearings, communications equipment, and major auxiliary equipment.

In addition, for the existing projects, an allowance is included for capital modifications, which reflects the gradual deterioration of the capital assets over the years. These funds are used for project units that can no longer be cost-effectively repaired under the O&M program. The amount allowed for this component in this study is substantially less than might normally be expected because of the high level of capital expenditures included in the rehabilitation estimate. For planned projects, such expenditures for capital modifications will be so far in the future as to have little impact on the annual cost.

Historic operating costs were obtained as a part of previous investigations [10]. The level of O&M costs was based on procedures from the Soviet times, so that the operating staff, as reflected by current rosters, was significantly larger than necessary. Since the breakup of the USSR, the scarcity of funds has rendered any current cost level for supplies and materials inappropriate for future planning.

3.2.3 Assessment of Proposed Projects

The hydropower resource within Armenia has been thoroughly studied throughout the past 70 years of development and all of the areas with substantial potential for generation have been identified. The two largest resources, the Sevan-Hrazdan and Vorotan River systems have been fully developed. There remain several other sites and areas with substantial potential for new capacity and high number of small hydroelectric projects that could be economically competitive due to the existence of irrigation or other diversion facilities.

For the purposes of the Least Cost Plan, existing information was reviewed for the major hydroelectric projects and some of the smaller projects. The three largest undeveloped projects that appear to be the most competitive are the Shnokh, Megri and Loriberd Projects. These projects have been evaluated at different times, under different study objectives. For this study, the most recent available information has been reviewed and compared for inclusion in the plan.

In addition to the larger hydro projects, there are a series of small projects that have been identified and could well be developed in the near and medium term. The actual development of these projects will depend on the available tariff for them. The higher the power tariffs for these projects, the more of these small projects can be economically developed.

The original work plan called for a selection of a limited number of projects for inclusion in the least cost plan that were considered to have a reasonable chance of being implemented within the development plan time frame. Costs for these proposed projects were updated (where possible) and analyzed in the screening analysis.

The estimates of average annual and monthly energy production that were included with the project descriptions were generally accepted as correct. Limited evaluation of the estimation process suggests that the estimates are slightly high. The estimates were usually based on monthly stream flow data which, while acceptable for a storage project, would usually provide high estimates for run-of-river projects. In addition, there was no mention of any allowance for scheduled and forced outages nor for transmission losses. The key characteristics of the proposed projects are presented in Table 2.

Table 2 Proposed Projects Key Data (2000$)

	Installed	Generation	Cost	
Project	**Capacity, MW**	**GWh/yr**	**Million $**	**$/kW**
Shnokh	70	270	121	1730
Megri	85	470	160	1882
Loriberd Group	56	186	97	1732
Akhurian	10	25	27	2754
Gekhi	5	21	11	2295
TOTAL	**226**	**972**	**416**	

3.2.3.1 Shnokh Project

The Shnokh Project is located in the north part of Armenia, comprised of a diversion of the Debed River, with additional collection of water where the diversion tunnel alignment crosses the Martsiget and Kitsum Rivers.

Available Information

The Shnokh Project has been studied several times in the past. Burns and Roe/Harza Engineering performed the most recent study, with the completed study report issued in 1998. The study was part of the USAID energy assistance program.

This study utilized the available layout and plan that had been developed in prior studies. Several changes to the original layout were recommended due to changing technologies and construction techniques. However, the project maintained its basic formulation of facilities. The authors of the latest study did not have complete access to the substantial drilling and sub-surface geotechnical program previously completed by the Armenian Hydro Institute. However the study and data apparently are sufficient for a clear idea of the comparative cost and benefit of the development.

A site visit was made as part of this study to confirm the setting in accordance with the design. The site is clearly compatible with the project layout proposed. Access to the project construction areas is excellent. Due to the importance of the road and railroad that run parallel to the river, maintenance of these facilities during construction may be expensive. The site visit confirmed that the facilities as planned fit the natural resource and could be constructed.

The Debed River in the area of the project is a rapidly flowing and high gradient river. The drop is fairly consistent over the length of the project reach with the river in a well-defined channel.

Project Description and Cost

The project is primarily a run-of-river and diversion project, as compared to a large storage project.

The site for the project intake does not lend itself well to providing a large dam. Thus, the primary features of the project are:

- a diversion weir on the Debed River
- an intake weir on the Marsiget River
- an intake on the Kistum River
- diversion tunnels 21 kilometers in length
- a regulating pond excavated on a high plateau above the Debed River
- pressure shaft, and penstock, to deliver water from the pond to the powerhouse
- a powerhouse containing two francis type turbines
- a connecting transmission line of about 5 km.

The project selected based on optimization studies has a capacity of 70 MW, with a design discharge of 35 cubic meters/second under a design net head of 228 meters. The average annual generation would be 270 GWh, or an average plant factor of 44 percent.

The project would be relatively easy to build, except for the extensive tunnel work. Of the total direct estimated cost of $114 Million, 55 percent is in underground water conveyance works, including the non-pressure tunnel and pressure shaft. The study estimated that about 50 percent of the tunnel would be driven through rock of poor or very poor quality. This expectation adds to the risk of the project considerably.

The total construction cost estimate of the project, including overheads, is $121.1 Million. This cost does not include interest during construction or other overhead costs during construction. The project is estimated to take four years for construction, plus two years of pre-construction planning and financing.

The project would divert water shortly downstream from the confluence of the Dzoraget and Pambak Rivers that form the Debed River. The proposed project develops most of the head from that point north to the border with Georgia and has few alternatives for developing the site potential.

The project does not have a substantial amount of environmental impacts, aside from the water diversion from the river during operations and the construction disturbance impacts. Few inhabitants would require relocation due to the project.

In summary, the Shnokh Project is a good quality project that would provide a domestic source of electrical energy to the grid. It would not be inexpensive to build and contains considerable risk due to the underground facilities. However, it is an option when importing fuels for thermal alternatives is considered.

3.2.3.2 Megri Project

The Megri Project is located at the southern border of Armenia with Iran on the Araks River. The Araks River upstream forms an international boundary between several countries. Furthest upstream it is the border between Turkey and Armenia. Downstream from that point it is the border between Iran and Nakhijevan, then Armenia and Iran and further downstream between Iran and Azerbaijan. There are several points where irrigation water is removed from the river in each of these countries/territories. About 110 km upstream of the project site, is the Araks multi-purpose reservoir that includes a 44 MW generating plant as well as irrigation works.

The section of the river between Iran and Armenia is about 40 kilometers long with a river fall of about 200 meters in this length. Consideration of the development of this resource has been made by both Iran and Armenia, with the apparent agreement allowing Armenia to develop the upper portion of the river by a diversion tunnel, and Iran to develop the lower portion of the river with a tunnel under its lands.

Available Information

There is very limited information currently available on the Megri Project. However, the Hydro Institute is working on an updated study on work previously done. The report on the study is not yet available as of this time but is scheduled for completion by the end of 2000. The Hydro Institute did provide a plan and profile of the proposed project that indicates consistency with the Armenian/Iran agreement on the use of the river. They also stated that subsurface studies have been done on the geology in the area, specific to the project.

The only other work that has been available on the project is from the 1996 Lahmeyer Least Cost Update Project. This project summary drew from preliminary designs that had been previously done by the Hydro Institute.

In addition to these limited plans, a site visit was made to the project area. The actual area of the intake could not be visited, due to the sensitive nature of the border with Nakhijevan. Several areas of the rock where the tunnel would be located were observed and the downstream tunnel portal and powerhouse areas both were visible. No photographs could be taken due to an apparent agreement with Iran, banning photography at or near the border.

The Araks River in the project area is a highly ribboned and sediment-laden water body. The river did not appear to be a high gradient body in the observed area. The Araks River valley and flood plain are well defined. Both borders are fenced and guarded. Some of the critical features of the project, including the diversion weir and the powerhouse, will be built in the flood plain area. This area is on the outside of the Armenian border fences and will cause a substantial amount of difficulty in implementation.

Other than the border considerations, access to the construction areas is good. The town of Megri would lie about in the middle of the tunnel alignment of the project and a border highway parallels the river, providing ample access for project works. As the railroad that also parallels the river is closed at the country's borders, the railroad would not be of use in constructing the project.

Project Description

The Megri Project features are primarily a dam and intake, tunnel and powerhouse. The intake weir for the project would be located just downstream of the Armenia/Nakhijevan border. The weir would be low, only 3-4 meters high and would include radial gates for passing high flows and sluicing of sediments.

The water conveyance to the project would consist of connection canals, a long tunnel and penstock. The dominant feature of the conveyance is the tunnel. According to the profile of the project by the Hydro Institute (Drawing 933-9-2), the tunnel would be a single, 7.8 meter diameter, un-pressurized tunnel. The tunnel would be 18.2 kilometers long. The alignment would contain several bends to maintain rock coverage when passing under creek beds and low elevation. The Laymeyer layout suggested that the project would require twin tunnels at 6 meter diameter over approximately the same length. While the Hydro Institute plan may be based on somewhat lower flows than the prior Lahmeyer plan, a tunnel diameter approaching 8 meters may be excessive for the natural rock formation in the region. However, the Hydro Institute indicates a relatively favorable rock condition, with about 60% of the alignment in Type 1 rock, 20% in Type 2, and 20% in Type 3. Type 1 is the best condition for tunneling.

The penstock for the project is 550 meters long, connecting the forebay to the powerhouse. The forebay would be a structure built at the downstream portal of the tunnel, collecting flows and maintaining a constant pressure on the turbines.

According to the Hydro Institute project profile, the Megri Project would develop 100 meters of head over the 18.2 kilometers of diversion. This amount is greater than the 70 meters estimated in the Lahmeyer study, but is apparently based upon more detailed studies. The project as currently formulated at the Hydro Institute would develop 85 MW and energy of about 470 GWh in a typical year.

The cost of the project was estimated to be US$ 165 million in the Lahmeyer study, for a 109 MW project. This total included a contingency and allowance for owner's costs, but did not include interest during construction. The Hydro Institute Study estimates a cost of US$ 160 million for an 85 MW project that would produce 470 MWh in an average year. No support details were available on this estimate at the time of this report.

In summary, the Megri project is feasible, but is not an inexpensive project for development. While it is on a large river, the river has several points of substantial diversion for irrigation purposes upstream. Further, the development requires a tunnel of 18.2 km for developing 100 meters of head. The construction will be complicated, as it is located in a border river, in the zone between the two fenced, guarded borders.

3.2.3.3 Loriberd Cascade Projects

The Loriberd Projects are located in the northern part of Armenia on the Dsoraget River. The projects as currently formulated would develop the head upstream of the existing Dsorages Project to the town of Stepavan. The current Loriberd cascade development plan was formulated during the Soviet period and has not been substantially reviewed or changed since that time. The project as planned, consists of three parts:

- The Malaya Project is a 1.8 MW development with 70 meters of head, that would divert water from the Urut River to the Dzoraget upstream of Stepavanan;
- The Loriberd 1 Project that would have a small impoundment on the Dzoraget River near Stepanavan, transmit water through 10.4 km of tunnel and 1.6 km of canal to an 8 MW powerhouse near the Gerger River;
- The Loriberd 2 Project that would use the outflow of the Loriberd 1 plant, plus diversion from the Gerger River, channeled 3.3 km to a 49.7 MW generating station.

The total generation capacity would be 59.4 MW. The estimated energy from the entire cascade project would be about 200 GWh.

Table 3

Plant	Design Head, m	Units in Plant	Design Discharge, m3/sec	Installed Capacity, MW	Energy, GWh/yr
Malaya	70	3	3.5	1.8	8.1
Loriberd 1	46.3	2	20	8.0	25.0
Loriberd 2	274.1	4	21	49.4	165.0

Available Information

The project as formulated was originally planned by the Hydro Institute. No drawings or other basic data was available from the Institute, but the plan and some background information were discussed with Institute Engineers. The project originally included a large dam at the Stepanavan site that stored water for the downstream cascade projects, including Loriberd 2 and Dzorages Project. The large reservoir option was abandoned, due to potential effects of raised groundwater on the local area and technical problems. However, the downstream portions of the project were not altered, except for reduced head at the Loriberd 1 plant.

The Hydro Institute represented that there has been a great deal of geological study and subsurface exploration at the sites for the cascade facilities. This information is not available for review at this time. The development of this project data is consistent with similar information collected in the past for the Shnokh and Megri projects.

Two studies addressed the project in 1994. The Lahmeyer Least Cost Plan Study, Reference 1, reviewed the project as part of the evaluation of hydroelectric resources. The work done was limited but included a quick cost estimate and output evaluation of the project. No changes were made to the original plan. The Lahmeyer report included some hydrological information and estimated plant production. The cost estimate produced by the Lahmeyer study is shown in Table 4.

The Harza/Burns and Roe Engineering did a more detailed study of the costs of the cascade in a study and report that same year, Reference 11. This study included a detailed quantity cost estimate of the plans of the Hydro Institute. The estimate was based on unit costs, quantity take-offs and used budget estimates for electrical/mechanical equipment. Table 4 shows the individual project and total cost estimate by Harza.

Table 4
Estimated Costs of Development
Loriberd Cascade (million $US)

Study	Malaya	Loriberd 1	Loriberd 2	Total
Lahmeyer, 1994	10.7	70.2	69.3	150.2
B&R/Harza, 1994	10.0	70.0	49.0	129.0

The costs in these estimates did not include interest during construction but did include contingencies.

The Harza study also included a design review of the proposed plan. The review did not analyze the overall formulation, but did recommend several items that might cut the costs of the development including simplifying the intake structures and ponding structures and possibly using different equipment at Loriberd 2 and Malaya Projects.

In addition to the available reports, a site visit was made to the region. The areas seen include the location for the Loriberd 1 intake in Stepanavan, the powerhouse location for Loriberd 1 and 2 and the intake area for the Loriberd 2 project.

Cascade Evaluation for Development

The Loriberd Project is likely too expensive for inclusion in the least cost plan, as it is now formulated. However, the project does have the potential to be developed in a different manner. During the prior Soviet period, when the project was planned, the planning objective most likely

included the maximum use of water for generation, within reason. Less focus was given to developing a least cost project from the resource. Furthermore, the use of pressure tunnels was generally avoided and certain types of equipment, particularly pelton turbines, were generally not utilized. Also, when the larger reservoir at Stepanavan was included in the plan, it allowed for considerable storage for a peaking project and for peaking purposes at Loriberd 2 and Dzorages. At the time when power was being wheeled into the large Soviet grid, the development of peaking power may have been more important.
Currently, the Armenian system has substantial capacity for peaking power. Moreover, the abandonment of the upstream large reservoir portion of the project limits the peaking potential of the sites.

It is possible that there is a more competitive project that can be developed at the Loriberd 1 and 2 sites. Without detailed topographical information, even a cursory evaluation of alternative schemes cannot be completed, but the potential exists to combine the sites to a single plant of higher combined head.

This change would entail eliminating the Loriberd 1 powerhouse and Loriberd 2 canals, and constructing a pressure tunnel/penstock system from the intake dam at Stepanavan to the Loriberd 2 site. The powerhouse at Loriberd 2 would have the benefit of the full head development of both current proposed plants, with fewer head losses within the system. It also would eliminate several expensive items from construction. The change in schemes would have the following listed positive and negative effects on the formulated project. Cost effects are based on the Harza cost estimate of 1994 for the project.

- About 4.8 km of open channel would be replaced by slightly less pressure penstock. The actual amount of pressure penstock cannot be determined without more detailed topography and other geotechnical information. However on a preliminary basis, the increased costs for the tunnel over the channel would be about $1 million/km or about $5 million.
- The head pond, penstock, powerhouse and generating equipment at the Loriberd 1 project would be eliminated, decreasing costs by $25 million.
- The dam and head pond at Loriberd 2 would be eliminated, decreasing costs by about $12 million.
- Pelton turbines could clearly be used at the Loriberd 2 site, with gross head available of over 340 meters. The pelton usage could result in using fewer turbines a simpler powerhouse (less excavation), and simpler sediment handling, as changing of turbine runners would be simplified. The equipment costs and construction costs would likely be quite a lot less than estimated in the current plan. Potentially a surge chamber would be necessary at the place of the head pond. No cost change has been estimated for these impacts.
- The elimination of the intake on the Urut River would decrease the water in the Loriberd 2 site. From the hydrological information available in the Lahmeyer Report, the lost generating flow to the lower project is estimated at about 7%.

- The Malaya Project should be re-considered on its own merits. Strictly as a power development, the 1.8 MW project at a cost of $10 million is clearly not justified. However, the provision of the additional water to the Loriberd Project might justify the project.

The estimated construction cost of a kilowatt-hour of energy from the Loriberd Cascade, as currently planned, would be about $0.65 ($129 million/200 million kWh). This value should not be used as a tariff, but is often a more reliable method of comparing potential hydroelectric projects to the alternative than a straight cost/KW capacity basis. The Loriberd value compares with $0.35 and $0.45 cents/kWh for similar values at the Megri and Shnokh sites. However, the Loriberd site appears more attractive, when it is considered that the site would develop about 350 meters of head over 15 kilometers, compared to 230 meters over 21 kilometers (Shnokh), or 100 meters over 18.2 kilometers (Megri). While the water volume is smaller at Loriberd than the other two projects, the facility size should help to lower costs.

In order to make the project more competitive, the project cost and output have been adjusted for the above changes. This preliminary study is not, however, on a level with other studies done for Shnokh or being done for Megri. It is possible that further study would indicate that the project costs would be higher or lower. Such a study should be done, if the project is attractive for the plan for Armenia.

If the two sites are combined to a single, higher head site, the net cost savings to Harza cost estimate would be about $32 million. Elimination of the additional water from the intake at the Urut River would decrease average annual energy production attributable to the Loriberd 2 site by about 7%, or 11.3 GWh and would at least lower the design flow from 21 m3/sec to 20 m3/sec. These changes would result in a project that produces about 186 GWh on an annual average basis at a cost of $97 million. This cost would be about $0.52/GWh, considerably less than the fully separate projects.

Not enough information is available to assess whether the Malaya Project should be constructed as part of the development. Clearly the 8.1 GWh/year produced at a cost of $10 million is not justified. However, the 8.1 GWh is generated by water used at the design head of 70 meters. If this same water is run through the 300 plus meters of gross head of the Loriberd plant, it would produce an additional 34 GWh of the total 186 GWh. The total costs of the diversion on this simple comparison would appear to be justified and critical to the project's economics.

Clearly, for further consideration past this least cost study, the Loriberd project should be re-evaluated with a study similar to the Shnokh study. The various parts and features of the project should be individually evaluated, with the two main focuses of the study being the possible combination of the two plants and the justification for the Malaya diversion/plant. The alignment, layout and constructability of the tunnel are of major importance to the feasibility of the site.

Moreover, it is likely that a smaller capacity, using a design flow of 15-18 m^3/sec, could still generate much of the estimated power, resulting in a lower unit cost of generated power.

For the least cost plan, it is recommended that the revised plan reconnaissance level estimates of 56 MW, 186 GWh and $97 million be used. The period for the construction of the project would remain at about 4 years, due to the tunnel length.

3.2.4 Summary of Mid Size Hydro Projects

The three projects described are all real potential projects for development within Armenia. These are the only remaining good sites above 50 MW within the country's borders. Although all are reasonable hydroelectric sites, none will be inexpensive to build, compared with the already existing projects in the major cascades.

Additional study is necessary on all three projects; however, sufficient basic information apparently exists in the form of hydrologic data, surface and sub-surface geotechnical information, and existing studies. The Shnokh Project is the only one with updated feasibility information. The Megri site may soon have such a study available from the Hydro Institute. The Loriberd Project needs to be re-formulated and re-considered with current planning objectives of producing low cost power to fit within the Armenian grid.

The development time of any of the three projects should be about 6 years, including a two-year period of final studies, design package development, construction arrangement and financial closure. The construction period for any of the three projects will be about 4 years.

The Shnokh Project and the Loriberd Projects could be done as private sector developments. However, to do so will likely take some hydroelectric policy emphasis on the part of the government. The project development should be implemented by a bid or other process to allocate the sites to a qualified development team. The government should take some final development steps to better define either or both projects before putting them out for private development, including making decisions on the nature of the potential bid process. There has been some interest by a private development group in acquiring the rights for development of both of the projects, but it is not clear that the power tariff that will be required to develop the projects would be competitive with other alternative sources of power.

The Megri Project will be more difficult to complete in the private sector. As it lies on an international border, the project will include numerous agreements with the Iranian government for access, border crossings, and right-of-ways that likely can only be done by government-to-government intervention. This project would be very difficult to develop and finance in the private sector.

3.2.5 Small Hydroelectric Projects

There remains a large potential base of variable quality small hydroelectric sites within Armenia that are not developed. Despite interest by the government and efforts by developers, only a few new projects have been brought on line in the past 5 years. Most of the development interest has been at the local level and has been thwarted by the combined problems of lack of development capital and lack of financing.

The experience in development of small, private-sector hydroelectric projects since the last LCP study by Lahmeyer has not been good. While there are a set of competitive projects available and several developers have pursued these projects, only two new capacity projects have been successfully brought on line. Despite the efforts of interested developers in other instances, no other projects have completed construction.

Both of the new capacity projects that are now operating were completed by Energia, Ltd. The projects are at Yerevan Lake, 600 kW and Kotayk Irrigation Works, 1.4 MW. Both projects were at existing impoundments with existing and usable water conveyance facilities. Thus, the only work necessary for completion was to construct a powerhouse, install equipment and modify the water conveyance structures.

Energia, Ltd. has been working on developing these small projects for about 5 years. They first developed the Yerevan Lake Project that has been operating for 3 years, then followed with the Kotayk Project that has just begun operating in 2000. Their success shows that projects can be completed but not without great patience and perseverance.

One developer from the United States has expressed interest in a small project, Djradzor (5-8 MW) since 1995, but limited progress has been made on the development.

Currently, there are three projects that have 1-year construction licenses issued by the Energy Regulatory Commission: these are the Talin-2 Project, the Shinarar Project and the Syunik Project. The latter is being developed by a charitable organization for its own use. There are also 5-8 projects that are in some stage of active development, although their potential success is speculative. Several factors combine to discourage the small hydro development, including:

1) Difficulty in raising capital for development and construction;
2) Unreliable payment history of Armenergo or other grid buyer;
3) Marginal return on the investment due to low energy rates in Armenia;
4) Immature regulatory process.

It is also fairly clear that attracting foreign capital investment to develop new capacity at small hydro sites is unlikely. There may be certain circumstances where international investors will participate in a particular project. However, the experience of the past 10 years on the international market indicates that most credible developers will not expend efforts or invest in projects that are below the 20-50 MW range. The small hydropower projects and market of Armenia are too small for large companies. Thus, the small hydro market will continue to be a local enterprise. Policies that are developed to encourage the industry should recognize this fact.

Availability of capital is the most difficult problem for the developers to overcome. Obtaining an international bank or multilateral loan is impossible due to the very small size of capital needed, and the local banks do not have sufficient capital or expertise in project finance to enable lending to the industry. Further, interest rates on Dram denominated loans are so high as to make projects financially infeasible.

For the past several years, an incentive rate of 25 drams/kWh has been available for new, small projects. However, the future of this incentive and the time frame when a project can receive this rate are not clear, so that developers cannot rely on the rate for future projects.

Resource Assessment

Despite the lack of project development, there remains considerable small hydroelectric potential and a number of economically developable sites within Yerevan. The total technical potential of small hydro sites within Armenia has been estimated to be about 400 MW. Of this total, only a fraction will likely be fully developed. The actual amount to be developed will be a function of the price to be paid for the power and available capital for development.

As it follows from the recent experience, the current tariffs in Armenia do not provide sufficient incentives to drive many projects to completion. However, even at this level, more projects should continue to "trickle in" to completion, as capital markets evolve and commercial transactions become more secure within the energy sector.

Several lists of potential projects have been provided for this study, from the Hydro Institute, the Ministry of Energy and a private engineering company. These lists include the projects that these agencies believe are the most likely for development. The projects are located all over the country and have different characteristics. However, most of the projects are small, less than 3 MW.

The Ministry of Energy list has 16 projects, with 52 MW of capacity and 180 MWh of energy on an average annual basis. The Hydro Institute list includes 37 projects with 70 MW of capacity and 237 GWh. Development of the full list of these projects would be approximately similar to completing the Shnokh Project. The list of projects provided by the private engineering group overlapped with the prior two lists and also included the larger projects.

Three undeveloped projects are on irrigation works:

Project	**Flow**	**Head**	**Capacity**	**Ave. Annual Prod.**
	M3/sec	**m**	**MW**	**MWh**
Talin 1	5.0	42.4	1.75	9.1
Talin 2	4.8	55	2.2	10.7
Akhurian	29	43	12	23.8

These projects are considered to be some of the most competitive projects that have not been developed. They are likely candidates for construction, since they already have water conveyance facilities available and require limited civil construction. However they remain undeveloped. The Talin-2 Project is currently under license and may be developed in the next few years. The Akhurian Project would seem to be an attractive project for development but has probably not been pursued due to the difficulty in raising capital for a 12 MW project.

Other examples of high quality sites that remain undeveloped at this time include:

Project	Flow	Head	Capacity	Ave. Annual Prod.
	M3/sec	M	MW	MWh
Gekhi	6	100	5.2	20.5
Djradzor	4	143	4.8	16.7
Chanachi 1-3	2	95-115	1.5-2	19.0 (total)
Volchi	6	93	5.2	22
Ashtarak	3	52	1.0	6
Akstev	12	56	5	14
Pambak	9	100	7.2	33

These projects have cost estimates that vary considerably by source and by project. However, for most of the projects, construction of the works would be fairly simple and in many cases much of the works are already built and in need of repair and completion. The typical estimate of costs is about $1200/kW. Since the projects generally have high heads (resulting in lower equipment costs) and would be built using local contractors and talent, these cost estimates are reasonable.

The actual amount of small hydropower that contributes to the future electrical energy supply will be dependent upon:

a) the need for and value of power in the Armenian market;
b) the energy tariff that is allowed by the Energy Commission or allowed by sales to third parties;
c) continued reform within the sector, increasing assurance that small producers will be paid fully and promptly the full tariff;
d) development and expansion of commercial lending sources within Armenia to allow lending to such enterprises as small hydropower.

To estimate the amount of small hydro to be used in the planning study, two scenarios have been projected. The base scenario anticipates that there will be little change to the current policy and price/tariff structure. The high scenario suggests that the existing limiting commercial conditions improve and more projects will be developed domestically with outside support. The high scenario is twice the amount of the low scenario and indicates that over the next 15 years, 70 MW of small projects would be developed. This estimate is aggressive, based on the history of only about 2 MW of new small hydro capacity coming on line in the past 5 years. However, the success of these two plants and the maturity of the Energy Commission to add some regulatory stability to the sector, should help more projects get completed.

The typical small hydroelectric project characteristics are:

Installed cost/kW (without IDC) = $1,200/kW
Average plant factor = 40%
Energy/year/MW = 3,500 MWh
Construction Period = 2 years

The annual additions that are projected are in some cases smaller than a few of the sites that are 5, 7 or 12 MW. However, it is reasonable to spread these out over several years, as it may be several months between commissioning of units, and the implementation of larger sites will average out with the smaller ones over some period of time. It is also expected that the larger sites will not be developed until later, due to capital limitations for the developers. It is currently much easier for them to raise small amounts of money than the large amounts for the multi-MW projects.

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